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A PREDICTIVE MODEL FOR AMBULATORY PATIENT SERVICE TIME

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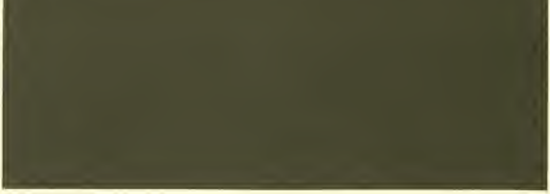

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Abstract

This paper reports results from one area of research on the general problem of resource scheduling and utilization in medical ambulatory care at the Lahey Clinic in Boston. Major areas in which it is possible to reduce scheduling errors in ambulatory care are noted, and research results in one--the development of more effective models of predetermining patient service time--are reported. Previous work with regard to service time has been centered around the development of the need for individual appointments--usually spaced at mean service time intervals. Here, an analysis is made of the variables which determine the expected length of a patient visit. Improved and implementable models for the determination of expected service time are noted based on the criteria of mean absolute scheduling error.

It is widely agreed today that a large segment of the population of the United States is receiving an inadequate amount of medical care. Quality considerations aside, there are two approaches to increasing the amount of medical care provided. Either medical care resources can be increased, or the utilization of current resources can be improved.

I. Conceptual Basis Underlying this Study

This paper reports on one aspect of the work currently being performed on the management of the ambulatory care process at the Lahey Clinic in Boston. The work is focussed on the second approach noted above--the improvement of resource utilization.

Typically the management of medical institutions has been fractured into many small components with supervisors exercising Anthony's[1] "operational control" over only tenuously coordinated small segments of the organization's activity. Effective "management control" which attempts to integrate operational subunits to best fulfill the needs of particular delivery systems has been rare in the medical industry. In many cases even the recognition that such systems (involving multiple departments and multiple functions) exist has been absent. Where efficiency has been a goal it has almost always been the suboptimal efficiency of each component part that has been considered--rarely the efficiency of the delivery system as a whole.

One such neglected system has been the complete "production" system which delivers ambulatory care in a multiple-specialist setting such as a group practice or hospital outpatient department. From a medical viewpoint, ambulatory care is a complex maze of possible diseases and care possibilities. From a management viewpoint, however, any ambulatory care system can be simply viewed along one possible action dimension by visualizing it as a large-scale resource scheduling problem.[5]

To maximize resource utilization in a production system, one would like to be able to develop an efficient schedule ahead of time--and then have the process proceed exactly as laid down by the schedule. Unfortunately, in the real world, many factors intervene to upset the schedule. These factors can be termed <u>sources of variability</u>

Much improvement has been accomplished in recent years in resource utilization in industrial multiple-resource systems through the careful definition of and reduction in these sources of variability. In industrial job shops, for example, much work has gone into determining the probability and duration of machine down-time. With this knowledge, preventative maintenance has helped to reduce untimely disruptions in schedules. In like manner, much effort has been expended to carefully develop expected product routings through the plant and good estimates of production time for each product at each machine group. With better estimates of expected resource utilization available, better planned and more effective production schedules have been developed with a concommitant increase in resource utilization.

In an effort to replicate these resource utilization gains in the

medical setting, work toward better understanding of the factors affecting demands on resources has been proceeding at the Lahey Clinic for the past four years. Some efforts have centered on more effective techniques of care delivery in the actual patient-physician encounter.[10] However, the problem of increasing resource utilization by reducing the amount of variability inherent in current ambulatory care scheduling techniques has been the central focus of the work.

As in the industrial sphere, there are many sources of schedule variation which exist in ambulatory care. Our original studies pointed to 17 problem areas.[7] Included among these were several <u>major</u> problem areas which caused schedules to be disrupted. The most significant of these were (1) an inability to predict the amount of time a patient would spend with each physician--a <u>service time</u> problem; (2) the difficulty of ascertaining before the patient arrived at the clinic which resources (physician and tests) he would need--a <u>loading and routing</u> problem; and (3) the presense of many data handling problems--an <u>information system</u> problem.

The effects of these factors on schedule variability can be significant. From the viewpoint of an individual practitioner, these results often are disconcerting. On any particular day, for example, a particular specialist can start the day with three consecutive patients, originally scheduled for fifteen minutes each, who require 35 minutes apiece. The physician thus quickly finds himself one hour behind in his schedule. In addition, due to incorrect (or unaccomplished) routing, the physician can also have an additional patient to be "worked-in"--a patient who drastically needs his particular expertise. If the physician also happens to

have started the clinic day 15 to 30 minutes late because he has been delayed at the hospital, the result is a massive overscheduling which is detrimental to both the physician (who is badly overworked on this day) and to his patients (who find themselves waiting for considerable lengths of time). When the reverse set of circumstances occurs, clinic resources are badly underutilized.

The work reported here is concerned with the first major problem--a better estimate of the service time to be allocated for each physician visit. Progress on the second problem area has been previously reported,[8] and efforts are continuing. Work on the third problem area (the information system) is proceeding at present.[11]

II. The Site

The Lahey Clinic, located in Boston, is a medical group practice of approximately 100 physicians. Its primary service is the treatment of ambulatory patients, although hospital care is available. One-fifth of Lahey patients are from Boston itself, but the practice is international in scope.

The scheduling of patients, for the most part, is done by a central appointment office. Working with information obtained from the patients or referring doctor, thirty secretaries schedule appointments for physicians and eight major medical tests. Patients coming for a complete physical examination are generally scheduled for an original sixty minute appointment with the primary physician. All other patient appointments are for either fifteen or thirty minutes depending on the sub-specialty.

III. Specific Purposes of the Service Time Study

A major assumption in all the work done in the area of scheduling of patients for clinic visits is that there are countless relevant variables in the patient-physician relationship. Under this assumption, any attempt to "accurately" preschedule the amount of time the patient will spend with the physician seems useless. In most settings this results in either of two possibilities. In one general case, no particular time allotment is scheduled for any patient. This is the familiar block scheduling system in which all patients are scheduled to appear at the same time. The other usual method is a single time period system, usually based on mean service time, which allows, for example, fifteen minutes for all patient visits (except, perhaps, for a complete physical examination). Neither of these two systems is very effective in dealing with the large variations actually found in service times.

A scheduling model which would provide better estimates of service time for each patient would result in the reduction of mean scheduling error. This reduction in the variance between actual service time and time scheduled would allow more precision in:

(1) determining the number of patients to schedule for a given clinic session.

(2) allocating a quantum of time for each individual patient.

(3) lessening the disruptive effect of "work-ins" (additional necessary appointments which have to be immediately inserted into the days's

schedule) by allowing them to be scheduled with those physicians and during those time periods when it is known that expected patient service demands are relatively low.

(4) eventual assessment of the efficiency of the scheduling of clinic operations through an on-going comparison of actual and estimated service times.

IV. Related Literature

Previous work with regard to service time has been aimed primarily at two objectives. One is the establishment of the relative superiority of the individual appointment systems over block systems. The second is determination of the optimum arrival patterns of patients for their appointments.

Initiating this line of investigation, Welch and Bailey using non-computer[14,2] Monte Carlo methods pointed out that extensive patient waiting was due to block scheduling and provided theoretical results which illustrated the superiority of individual-appointment time systems. They suggested that patients be scheduled according to the mean physician service time. A dozen years later, White and Pike constructed a mathematical model taking into account patient punctuality, a factor which had not been considered by Welch and Bailey.[15] When patients are punctual, White and Pike suggested that an appointment scheme be used in which two or three patients are called at the start of the clinic session and the

others are called at a rate which approximates the doctor's mean consultation time. When patients tend not to be punctual, they recommended that small blocks of three patients each be scheduled to arrive at time intervals which are three times the average consultation period.

Other mathematical models have been utilized to shed light on the problem, as illustrated by the work of Soriano.[12,13] Working at the Wilmer Opthalmological Institute at Johns Hopkins, Soriano experimented with patient scheduling systems. He modeled the pure block appointment system and the individual-appointment-time system. He also tested a "mixed block" system of appointments (similar to White and Pike's).

Using computer simulation, Fetter and Thompson[3] also modeled ambulatory scheduling in 1965. Other experiments, such as that of Villegas at Hennepin County General Hospital,[16] Johnson and Rosenfeld in New York City Hospitals,[5] and work at Massachusetts General Hospital[9] have served primarily to confirm the case for individual appointment systems.

Yet all of this work dealing with service time, and its effect on the patient and physician, has implicitly or explicitly utilized only a single service time period for routine appointments--usually the clinic mean service time.

V. Method of Study

Our work was thus aimed at identifying those variables which clearly affected service time and at incorporating these variables in a useful scheduling model. The method of study consisted of three steps. These were:

(1) The collection of data for a two-week period

from a three-physician specialty clinic.

(2) The determination of significant explanatory variables from:

a. Correlations of continuous variables and service time.

b. Contingency tables comparing service time and the various discrete variables.

c. A regression model using dummy variables--checking for cross correlations.

(3) The building of predictive models for service time scheduling and the evaluation of these models in comparison with available benchmarks.

Data Collection

Data were collected on 19 variables for each of 224 cases. (The topics are included in Table 1.) The models were constructed utilizing 169 cases. The efficacy of the model was then tested on the remaining 55 cases.

The observations included all returning patients (not requiring a complete physical examination) seen in a two week period by the three physicians in the thyroid section of the Department of Internal Medicine. This department was chosen because the physicians and nurses were receptive to the idea of being "observed," the physicians perform a wide range of medical practice, and the department was felt to be typical of Lahey specialty practice.

TABLE I: VARIABLES ON WHICH DATA WERE COLLECTED

		Data Source
1.	Service time	Observation in clinic
2.	Patient seen by a resident (yes/no)	Same
3.	"Need for additional attention" (estimated by physician - (none, some, much)	Same
4.	Complications to diagnosis (yes/no)	Medical record
5.	Most recent diagnosis	Same
6.	Patient's name and number	Daily schedule
7.	Attending physician	Same
8.	Scheduled consultation (yes/no)	Same
9.	Scheduled tests (yes/no)	Same
10.	Purpose of the visit (follow-up, consult, check-up, tests, results)	Appointment office or medical record
11.	Appointment method (Doctor/patient)	Same
12.	Patient's age	Same
13.	Patient's sex	Same
14.	Number of months since last visit	Same
15.	Number of visits in last three years	Same
16.	Hospitalized in last three years (yes/no)	Same
17.	Patient a company executive (yes/no)	Same
18.	Patient a clinic employee (yes/no)	Same
19.	Patient's home town	Same

Search for Significant Explanatory Variables

The initial step in the search for explanatory variables was to determine the correlation between the continuous variables and service time.+ As shown below, only the date of last visit was correlated with service time.

Continuous Variable Correlation with Service Time

Variable	Correlation (and Significance)
Age	0.06 (Not Significant)
Last visit (mos.)	0.28 (Significant at .01 level)
No. of visits (3 years)	0.05 (Not Significant)

The discrete variables hypothesized to be important were then tested by contingency tables against service time. The following variables were significant: scheduled consultation,* physician,* need for attention,* appointment method,** and purpose of visit.**

In continuing the search for significant explanatory variables, a regression model was constructed. This model considered service time as the dependent variable and the other variables shown in Table I as independent variables. The regression equation was run using the multiple-regression portion of the Statistical Package for the Social Sciences.[6] The results of the regression analysis, using the best twelve variables, is shown in Table II.

+A scatter diagram showed linear relationships

*using X^2, $p<.05$

**using X^2, $p<.1$

With the regression results added to the correlation and chi-square analysis, the search for explanatory variables led to some positive conclusions with regard to the relationship of several variables to service time. The following variables appeared most significant: (1) the date of last visit, (2) the "need for attention", (3) the physician and (4) the presence of a "scheduled consultation". The "purpose of the visit" appeared significant only for the "check-up" category.

Each of the four major indicated variables appears logical in its impact. The longer a patient is away from the clinic, the more time he is apt to need from the physician for several reasons. For one thing, the physician must take more time to refresh his memory about the patient as the appointment interval increases. Moreover, the patient is apt to have an increased number of physical changes with increasing time--and will therefore need a more intensive examination.

With respect to the other variables, it is apparent that physicians do have differing work styles. One of the three physicians in the sample spends approximately 50 per cent more time with his average patient--although the patient mix is indistinguishable. In addition, patients have differing "needs for attention" based on psychological as well as physical factors. Finally, the presence of a scheduled additional consultation should lower service time since the examining physician can leave at least one major area of inquiry to one of his colleagues.

The Predictive Models

Using the results obtained in the search for significant explanatory

TABLE II: SUMMARY OF REGRESSION ANALYSIS (STEP-WISE REGRESSION)

Variable	Coefficient (B)	Std. Error (S)	t-test ($t \simeq \lvert B/S \rvert$)	
(Constant)	17.08		(2-sided test) d.f.≈∞	
Last visit	0.15	0.07	2.26	$p<.05$
Need attention				
Significant	8.33	2.27	3.67	$p<.001$
Little	6.57	1.71	3.82	$p<.001$
Physician				
Physician 1	-5.89	2.02	2.92	$p<.005$
Physician 2	-5.03	2.04	2.47	$p<.02$
Age	0.10	0.05	2.28	$p<.05$
Scheduled consult.	-4.73	1.51	3.14	$p<.002$
Doctor made appt.	-3.24	1.91	1.69	$p<.1$
Purpose of visit				
Check-up	7.35	2.73	2.68	$p<.01$
Consult	3.60	2.47	1.45	$p<.2$
*Follow-up	1.79	1.77	1.02	NS
G.I diagnosis	-5.72	2.98	1.92	$p<.1$
*Out of state	1.98	1.71	1.16	NS
*Seen by resident	-2.43	2.45	1.00	NS
*An executive	-3.47	3.45	1.00	NS

*Not used in final model

Summary

$R^2 = .398$

Standard Error of Residual = 8.98

$F(15,153) = 6.75$, $p<.01$

variables, three predictive models were constructed. The new predictive models were then compared with the results of the current system. In the new models, the initial output was in tenths of minutes. However for implementable scheduling purposes the patient was assigned a 15, 20 or 25 minute appointment based on the value of the output of the model.

One model was the regression model. A second model, shown in Table III, considered just the two easily obtained variables, the "physician" and the patient's "need for attention" (either "none" or "some" additional attention).* The value in each cell is the mean time of the patients in this category adjusted to the nearest five minutes for ease of scheduling. Utilization of the table is straight-forward. For example, a patient of physician #1 who was noted by that physician to need no additional attention would be scheduled for 15 minutes.

TABLE III: "SIMPLIFIED" TWO-VARIABLE SCHEDULING MODEL

		"Physician"		
		1	2	3
"Need for Additional Attention"	None	15	20	15
	Some	25	25	25

*Physicians have agreed that it is feasible to routinely supply the "need attention" value for each returning patient at the conclusion of the prior visit--therefore it would be available to the appointment secretaries for all returning patients.

The third model was merely the mean time for each visit; i.e., 19 minutes (adjusted for scheduling purposes to 20 minutes). As noted above, the results of these models were compared to the present system which uses 30 minutes as an appointment interval*, and to each other.

For the 55 test cases, the mean absolute error of prediction using both the "simplified" and "regression" models was less than the model using the mean(6.9 and 6.5 compared to 8.2 as shown in Table IV). Each is significantly lower than the mean model--$p < .01$ using a t-test. The mean errors of both new scheduling models are also obviously significantly less than the mean error of the current system.

TABLE IV: MEAN AND STANDARD DEVIATION OF ABSOLUTE SCHEDULING ERRORS IN MINUTES

	Mean	Standard Deviation
Regression	6.5	6.9
Simple	6.9	6.5
Mean	8.2	7.4
Present System	14.1	7.8

*This 30-minute interval is, in effect, the nearest multiple of 15 minutes greater than the perceived average time per visit. It is realized both by the physicians and the Appointment Office that this period of time is "too long", therefore additional patients are "worked-in" to the physicians' schedules. Because it is not known which patients will take how long, many of these "work-in" patients are scheduled as additional patients at exactly the wrong time (i.e. they are added to the schedule during precisely the period when one or more patients needing a lengthy amount of time are scheduled.)

VI. Discussion

It is thus seen that there are variables which, if utilized in the scheduling process, can help to eliminate some of the random variation in service time which plagues effective, consistent resource utilization in ambulatory care facilities. The findings may not hold for all clinics, but preliminary evidence suggests it will for many.[4] In the case of this particular clinic, the findings (most particularly the two-variable model) can be translated into action which will improve the scheduling process. The elimination of some of the variation in the scheduling process through more precise knowledge of service times can lead to a reduction in the extremes of patient waiting time and to some equalizing of the daily service loads of physicians. One computer simulation, using actual patient data, of the gains possible through better service time allocation shows a reduction of more than 25 per cent in average patient waiting time.

These findings are currently being utilized at the Lahey in a simple, but hopefully effective, manner. Forms have been designed to allow physicians to choose any of four possible service times for their returning patients--instead of the traditional single time. This is a mathematically inexact, yet behaviorally effective, extension of the concept that the variables of "physician" and the physician's estimate of "need for attention" are the best prediction of an accurate value for patient service time.

Although the findings are not applicable at this time to most hospital outpatient departments where patients are seen on a block system, or by different physicians from one month to the next, etc., they may well be

applicable in the future. In consonance with the HMO concept, and several other trends, many outpatient departments are moving toward individual appointments, full-time physicians, and a greater interest in a continuing physician/patient relationship. Under these circumstances, the findings are of interest not only to the growing number of group practices and HMO's but also to hospital outpatient departments. If the estimate by Dr. Walter C. Bormeier, in his farewell address before the AMA's 1971 Annual Convention, that 75 per cent of the doctors active in patient care will be in a group practice by the end of the decade holds true, the findings are of particular interest.

At the risk of being trite, it is necessary to treat management problems in the medical area in the way that industrial problems have been met. All factors involved in a delivery system must be considered. Individual problems must be coordinated into effective delivery systems for utilizing the all-too-scarce resources in the medical field.

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